Dual-Phase Inorganic Membrane for High Temperature Carbon Dioxide Separation

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Abstract

OBJECTIVE

This project is intended to expand upon the previous year's research en route to the development of a sustainable dual-phase membrane for CO_2 separation.

ACCOMPLISHMENTS TO DATE

As was the case with the previous year's research, metal-carbonate dual-phase membranes were prepared via the direct infiltration method. It was observed that if the support was at temperatures below 500°C prior to infiltration, molten carbonate solidified on the surface of the support. The solidified carbonate restricted infiltration into the pores of the membrane. However, when the supports were preheated to temperatures above 500°C, molten carbonate sufficiently infiltrated the pores of the membrane.

Based on the porosity and density of the support, the maximum uptake of molten carbonate for a single support was found to be 0.264g. Calculations show that 80% of the pore volume of the 0.5 media grade metal support was filled with the molten carbonate. Information obtained from EDS and SEM imaging confirmed that molten carbonate completely infiltrated the pores on both the contact and non-contact size of the support. Furthermore, it was found that the pores within the supports had to be less than 9 μm in order to maintain the stability of the dual phase membrane. Pores larger than 9 μm would be unable to hold the molten carbonate in place during permeation tests, rendering the membrane ineffective.

Permeation tests for CO_2 and N_2 at 450-750°C showed very low permeance ($< 5.0x \cdot 10^{-9}$ moles/s·m^2·Pa) of those two gases through the dual phase membrane. Low permeance was expected for CO_2 and N_2 due to the lack of ionization of those species. Permeance of the CO_2 and O_2 mixture was much higher, indicating that the gases did form an ionic species, CO_3^{2-}, enhancing transport through the membrane. It was observed that permeance of CO_3^{2-} reached an approximate maximum

value of $2.6x \cdot 10^{-8}$ moles/s·m^2·Pa at 650°C. Above 650°C, permeance of CO_3^{2-} decreased rapidly, despite the fact that predictions indicated permeance should have continued to increase with the continued rise in temperature.

XRD data obtained from the surface of the membrane indicated the formation of lithium iron oxides ($LiFeO_2$ and $LiFe_5O_8$) on the surface of the support. These lithium iron oxides are known to have low conductivity. Therefore, formation of the oxides on the surface of the membrane drastically reduced the flow of electrons to the CO_2/O_2 gas mixture. Reduction in electron conductivity inhibited the formation of the CO_3^{2-}, thus explaining the decrease in permeance of CO_3^{2-} as time and temperature increased.

FUTURE WORK

These results indicate that the use of stainless steel supports in a high temperature oxidative environment can lead to decreased performance of the membranes. This revelation has created the need for an oxidation resistant support, which can be achieved with the use of a ceramic-type membrane. Future research efforts will be directed towards preparation of a new ceramic-carbonate dual phase membrane. The membrane will based on an oxide ceramic support that has a higher oxidation resistance than the metal support and high electronic conductivity (1200-1500 S/cm) in the interested temperature range (400-600^{o}C).

LIST OF PAPERS:

- S. J. Chung, D. Li, J. H. Park, J.-I. Ida[1], I. Kumakiri and J.Y.S. Lin, "Dual-phase inorganic metal-carbonate membrane for high temperature carbon dioxide separation", Ind. Eng. Chem. Res., Submitted (2005)
- S.J. Chung, D. Li, J.I. Ida, J.H. Park, J.Y.S. Lin, "Dual-Phase Inorganic Membrane for High Temperature Carbon Dioxide Separation", Poster, *AIChE Annual Meeting*, Austin, TX, Nov. 7-12, 2004
- S.J. Chung, *J.H. Park*, D. Li, J.I. Ida, J.Y.S. Lin, "Dual-Phase Inorganic Membrane for High Temperature Carbon Dioxide Separation", ACS *National Meeting, San Diego, CA*, March 13-18, 2005

STUDENTS SUPPORTED

S.J. Chung, D. Li and Q, Yang